Implementation and Determination of the Three-Dimensional Geodesic Structures in the Olinda's Historical Site

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Key words: Three-dimensional geodesic structures, geodesic surveying

SUMMARY

The three-dimensional geodesic structures are fundamental to engineering projects, such as location and survey of building structures, cadastral surveying, road and railway projects, positioning and machine control, as also as, monitoring of geodesic structures. These structures allow the georeferencing and 3D reconstruction of surfaces and objects. A frequent difficulty in three-dimensional reconstruction and in the topographical/geodesic surveying is the absence of planialtimetric reference points in the neighborhood of urban and rural properties in Brazil. One solution for this difficulty is the use of Geodesic Positioning Satellite System (GNSS - Global Navigation Satellite System) technology, integrated to the planialtimetric measurements to determine a set of field reference points, which will define geometrically the elements surveyed on the ground or on the object, these can be natural or artificial ones. The determination of the inaccessible high points in the architectural structures, such as targets located in the structures of the churches tower, is very important, although they are inaccessible, they can be visible from others places and they are more difficult to be destroyed by human actions. Thus, it is shown to be a relevant study involving terrestrial methods of measurement, such as: forward and backward intersections, geometric leveling, trigonometric leveling with short distance targeted, and spatial positioning GNSS methods, for the definition of field reference points and field-object points located in rough terrain. The geodesic structures were implemented in the Historic Site of Olinda employing GNSS receivers, total stations and digital level. The historical site of Olinda was recorded by UNESCO as Historical and Cultural Heritage of Humanity. The study area is located in the Center of the busiest site with a quite roughly relief. This area has been studied since 2007 involving Research of Scientific Initiation and Pos-Graduation Course. This paper aims to present the realized experiments for the implementation and definition of geodesic structures in environments with very rough relief, including large old houses and historic monuments.

RESUMO

As estruturas geodésicas tridimensionais são fundamentais para os projetos de Engenharia, tais como: locação e levantamento de estruturas de edificações prediais, levantamentos cadastrais, traçados de rodovias e ferrovias, posicionamento e controle de máquinas, assim como, monitoramento de estruturas geodésicas. Estas estruturas permitem o georreferenciamento e reconstrução 3D de superfícies e de objetos. Uma dificuldade freqüente na reconstrução tridimensional e nos levantamentos topográficos/geodésicos é a

ausência de pontos de referência planialtimétricos nas proximidades dos imóveis urbanos e rurais brasileiros. Uma solução para essa dificuldade é a utilização da tecnologia de Posicionamento Geodésico por Satélite (GNSS – Global Navigation Satellite System) integrado a medições terrestres planialtimétricas para definição de um conjunto de campo de pontos de referência, o qual definirá geometricamente os elementos levantados sobre a superfície do terreno e do objeto, estes podendo ser objetos naturais ou artificiais. A determinação de pontos altos inacessíveis nas estruturas arquitetônicas, como por exemplo, alvos contidos nas estruturas de edificação situados em torres de igrejas, é importante, pois apesar de serem inacessíveis, tornam-se visíveis de outras localidades e mais difíceis de serem obstruídos por ações antrópicas. Com isso, mostra-se ser de relevância um estudo envolvendo os métodos terrestres de medição, tais como: interseção à vante e à ré; nivelamento geométrico, nivelamento trigonométrico com visadas curtas; e métodos de posicionamento espacial GNSS, para a definição de campo de pontos de referência e campo de pontos-objeto localizados em terrenos acidentados. As estruturas geodésicas foram implantadas no Sítio Histórico de Olinda empregando-se receptores GNSS, Estações Totais e Nível Digital. O Sítio Histórico de Olinda foi tombado pela UNESCO como Patrimônio Histórico e Cultural da Humanidade. A área em estudo localiza-se no Centro de maior movimentação comercial e com relevo bastante ondulado. Essa área vem sendo estudada desde 2007 envolvendo pesquisas de Iniciação Científica e de Mestrado. Este trabalho tem como objetivo a apresentação dos experimentos realizados para a implantação e definição de estruturas geodésicas em ambientes diversificados pelo relevo acidentado, caracterizada pela construção de casarios antigos e monumentos históricos.

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1. INTRODUCTION

The three-dimensional geodesic structures are fundamental to engineering projects, such as: location and surveys of building structures, cadastral surveying, road and railway projects, positioning and machine control, and monitoring of deformations of geodesic structures themselves, allowing the georeferencing and the 3D reconstruction of terrestrial topographical surfaces, artificial objects, for example, building constructions.
A frequent difficulty in the three-dimensional reconstruction and topographical/ geodesic surveying, is the lack of planialtimetric reference points near the urban and rural properties. One solution for this difficulty is the use of Geodesic Positioning Satellite System technology (GNSS - Global Navigation Satellite System) integrated to the terrestrial planialtimétric measurements for definition of a set of field reference points that will define geometrically elements surveyed on the surface of ground and natural or artificial objects, located in a given reference system.

The determination of the high points in inaccessible architectural structures, such as target of the buildings located on church towers is very important in one geodesic structure, despite of being inaccessible from other locations, are visible in the others places and will be more protected by devastation of human actions. Thus, it is more relevantly to a study involving methods of terrestrial measurements, such as: forward and backward intersection, geometric leveling, trigonometric leveling with short sights, electronic tacheometry, in addition to the geodesic positioning satellite to the field reference points definition and field object points located in rough terrain. The aim of this paper is to present the methodology used for the implementation and definition of the three-dimensional geodesic structures to present three-dimensional buildings located in urban sites with the presence of rough relief making use of planialtimetric measurement methods.
The experiments were conducted in the area of the Historic Site of Olinda, called Area Test. The geodesic structures implanted in Olinda Historic Site were measured three-dimensionally and densified employing GNSS receivers, Total Station and Digital Level. In the following will be approached the three-dimensional geodesic structures and planialtimetric measurement methods.

2. THREE-DIMENSIONAL GEODESIC STRUCTURES

Three-dimensional geodesic structures can be defined as fields of planialtimetric points materialized and accurate. These fields of points represent the reference for the establishment of geodetic positions to arrive at global, regional and local (TORGE, 2003). Three-dimensional geodesic structures are formed by planialtimetrics geodesic networks and

gravimetric networks. In this paper will be treated local three-dimensional geodesic structures.These are implemnted primarily for engineering projects, among other geophysical investigations and for geodynamic procedures determination spatially limited (TORGE, 2003).
The definition and implementation of geodesic structures are dependent on technological developments. Therefore, it will be visualized distinct measurement procedures, materialization and points detection. Then the geodesic structures have one-dimensional, two-dimensional and/or three-dimensional character. In SOUZA (2012) and GAMA (2008) are approached the geodesic structures employed in this work.

3. PLANIALTIMETRIC MEASUREMENT METHODS

For the field reference points measurement, in the present paper, it was employed planialtimetric methods of surveying such as: GNSS, forward and backward intersection, as well as, geometric and trigonometric leveling with short sights.

3.1 Static Relative Positioning Method of GNSS

The relative positioning can be obtained by the static method. The static method generally, uses the double phase difference (DD) as observable. Two or more receivers collect data simultaneously from the satellites for at least twenty (20) minutes to a few hours. Enables an accuracy around 1.0 to 0.1 ppm or better than that. For extensive baselines (greater than 15 km) are employed receivers with dual frequency (MONICO, 2008).
For relative positioning are assigned to various methods, among them can be mencioned the static and "stop-and-go" methods. Further information regarding to these methods are acquired in the following bibliographical references: (SEEBER, 2003), (MONICO, 2000), (LEICK, 1995), (SEGANTINE, 2002) and (HOFMANN-WELLENHOF et al., 2001). General Standards and Specifications for GPS Surveys by IBGE, PR Resolution 22, of 7/21/83, refer to these surveying methods and determine the conditions to be applyed in all surveys with GPS in Brazil.

3.2 Terrestrial Planialtimetric of Measurement Methods with Total Station

In this paper the terrestrial measurement methods are interconnected to the positioning satellite methods. In the following are defined the used terrestrial measurement methods. They are ordered according to the types of observations made by the Total Station. The determination of the planimetric coordinates were separated of the altimetric determination.

3.2.1 Forward Intersection Method 2D

Two cases were approached in (SOUZA, 2012). At the first forward intersection occurs by internal angles measurrments α and β (Figure 1) belonging to the triangle formed between the known coordinates vertices of P_1 and P_2 and the unknown P_N. In this case the known coordinates vertices with P_1 and P_2 are intervisible each other. In the second the forward intersection occurs by directional angle measurements the (Figure 1), in this case the known

coordinates vertices P_1 and P_2 are not intervisible each other.
In the case of the forward intersection by means of horizontal angles are given the coordinates of the vertices $P_1(y_1, x_1)$ and $P_2(y_2, x_2)$ as illustrated in (Figure 1) and the directions measurements, $r_{1,N}$, $r_{1,2}$, $r_{2,N}$ and $r_{2,1}$, the azimuth $t_{1,2}$ and the distances from these coordinate vertices are calculated. From horizontal direction measurements with Total Station, will be got the angles α and β.

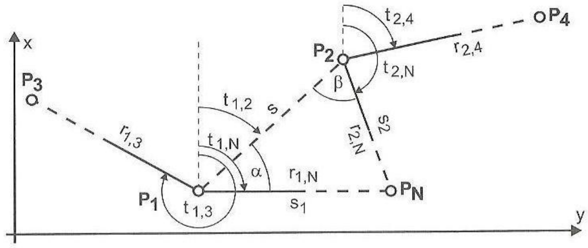

Figure 1: Forward intersection through the directional angles. Source: GRUBER and JOECKEL (2011).

In the case of forward intersection through the azimuth angles the stations P_1 and P_2 are not intervisible each other, so it is necessary that known stations in the vicinity of the stations P_1 and P_2, in (Figure 1) represented by P_3 and P_4, so that they can be determined the orientation angles (azimuth angles).
The determination of a point may occur by at least two stations with known coordinates. When using more than two known stations or performed abundant measurements the coordinates can be adjusted by the Least Squares Method (KAHMEN, 1997) and (WOLF; GHILANI, 1997).

3.2.2 Forward Intersection 2D

The method of forward intersection can be subdivided into three situations. They are characterized according to the type of observations that are performed to determine the unknown station: intersection by direction measurements, intersection by means of distance measurements and intersection by combined measurements of direction and distance.
The method of backward intersection through combined distance measurements and direction, used in this study, can be used when you want to determine the coordinates of the topographic station under which a Total Station or electronic Tachymeter is installed. To do so they must be measured: the distance between the unknown station and occupied by the Total Station and one of the known coordinates station D_{EA} and the directions between the unknown station occupied by Total Station and two known coordinates station of resulting in the angle α. This method is illustrated in (Figure 2).

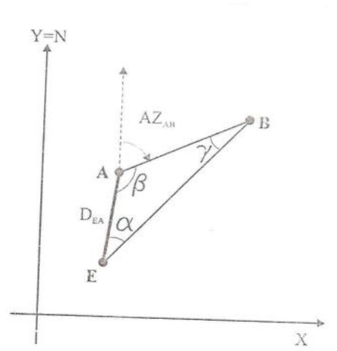

Figure 2 – Free Station Method. Source: ERBA et al. (2005).

3.2.3 Trigonometric Leveling Method

Characterized as trigonometric leveling the altimetric transference performed by zenithal angle measurements and inclined distances and/or reduced to the horizont. In this work the trigonometric leveling was done with short distances.
An advantage of the determination of the trigonometric height is their employability in spots that are inaccessible, such as church towers, high points of civil works. At these points are not possible to measure the horizontal distance "a" to the station located on the ground. In this way the horizontal distance "a" must be determined indirectly from the help of a triangular horizontal plane as shown in (Figure 3). To obtain the horizontal distance "a" is placed near the station a base AB, which from their extreme points A and B is intervisible the high point T.

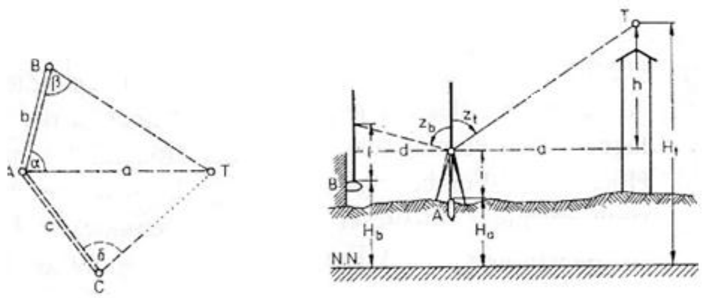

Figura 3 - Trigonometric Leveling of inaccessible points. Source: KAHMEN (2005).

The accuracy of the height transportation through the trigonometric leveling is essentially dependent on the measured angles, heights of the instrument and the target, as well as atmospheric refraction. The influence of instrumental errors in height on the height transportation is independent of the distance and for short distances can play an important consideration (RESNIK and BILLl, 2003).

3.3 Terrestrial Method of Altimetric Measurement with Digital Level

The altimetry reproduces the true shape of the land and leveling methods are used to establish the level differences (JORDAN, 1944).

The Geometic Leveling is the process that establish the level difference in among the ground points through horizontal sights, in vertical rods positioned on the points, with a certain level (NBR 13.133/1994).

To determine the altitude of point B (Figure 4) above the reference surface defined by reference level A, the level difference Δh_{AB} is determined from the simple leveling sections. For that distance AB is subdivided by parts separated by points of change $W_1, \cdots, W_n$ of at most 100m, the differences level being individual h_1, h_2, ..., h_n observed and added to one another.

$$\Delta h_{AB} = h_1 + h_2 + \cdots = \sum h = \sum Backward - \sum Foreward$$

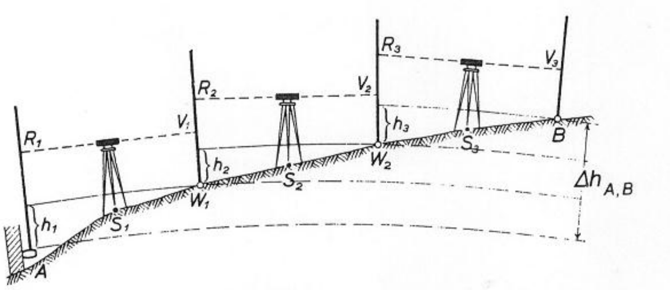

Figure 4 – Leveling circuit between points A and B. Source: KAHMEN (1997).

4. IMPLEMENTATION AND DETERMINATION METHODOLOGY FOR THREE-DIMENSIONAL GEODESIC STRUCTURES

This section presents the implementation and determination methodology of the geodesic structures, whose experiments were performed at the Historic Site of Olinda. It was implemented a set of benchmarks points in the field by applying the static relative positioning method with GNSS and Terrestrial Measurement Methods: forward intersection, backward intersection and trigonometric leveling with the use of a Total Station and the geometic leveling method with the use of a Digital Level. Following are the materials, the characteristics of the test area, the definition of the planimetric and altimetric reference system, as well as, the field measurements of the points of the experiments.
The precision indicator used in carrying out the surveying applied to engineering for the GNSS Surveying System methods, as well as, Total Station and Digital Level, obeyed the confidence level of 95%.

In the field data collection and in the observations processing and adjustments were used the following equipment:

• Geodesic Receivers of dual frequency (L1/L2);
• Total Station;
• Digital Level;
• Post-processing Software;
• Developed Applications in EXCEL spreadsheets

4.1 Definition of the Experiments Area

The test area is located in the city of Olinda, Recife Metropolitan Region. The same part of the Historic Site of Olinda, consisting of historic buildings for residential use. Figure 5, excerpted from *Google Earth* (2009), presents a sketch of the configuration of the terrestrial stations and triangulation high targets located in the Towers of Churches: Nossa Senhora da Misericórdia, Catedral da Sé and Nossa Senhora do Carmo.

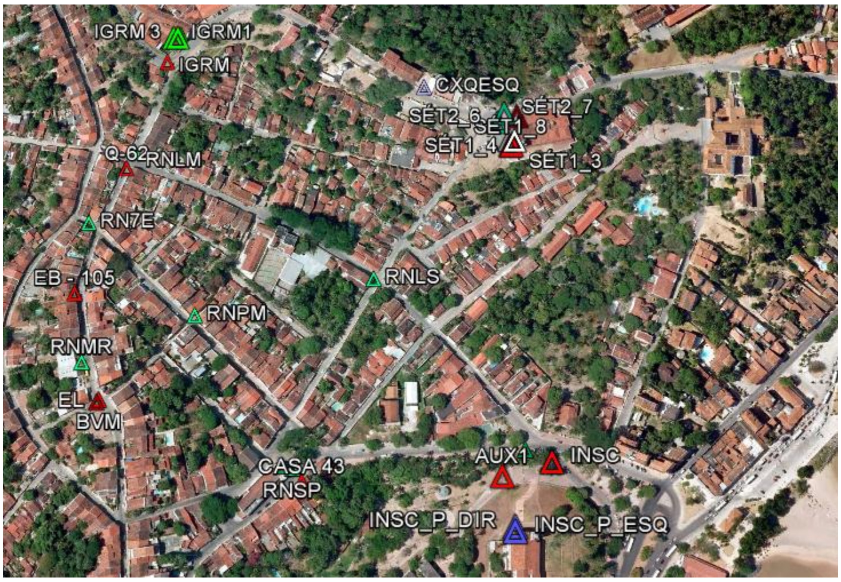

Figure 5 - Sketch of the aerial view of the field representation of the reference points. Image: *Google Earth* 2009. Source: SOUZA (2012).

4.2 Planimetric and Altimetric Reference System Definition

The set of the field reference points is classified into three (3) categories: implemented field reference points for the positioning execution of GNSS, implemented field reference points for execution of the terestrial measurements methods with Total Station and implemented of the field reference points for execution of the terrestrial mesurements methds with Digital Level. The implementetion of the field points metodology for GNSS are approached by (GAMA, 2008) and (SOUZA, 2012).

Thus, Olinda was covered with implantation and densification of a set of the field points:

- Planimetric Field of Reference Points

This field points is divided into two. The first implemnted with GNSS, consists of 5 (five) stations (BVM, MR, IGRM, HOUSE 43 and INSC). The materialization of the vertices was held with pins riveted between the curb and/or sidewalk and wrapped with high strength epoxy adhesive (Sikadur 32). In (Figure 5) there is illustrated a sketch of the location of this field points. The second field of points, implemented by Total Station by poligonation methods with forced centering and backward intersection. It consists of nine (9) stations (BVM, MR, IGRM, HOUSE 43, INSC, EB - 105, Q - 62, and AUX1 EL). The materialization of stations (EB - 105, Q - 62, AUX1) was performed with riveted pins between the curb and involved with mass epoxy adhesive. The stations (BVM, MR, IGRM, EB - 105, Q - 62, AUX1, EL) were used for transportation of the planimetric coordinates for targets located in the inaccessible peaks and towers of churches.

- Altimetric Field of Reference Points

The altimetric field points was implemented with Digital Level through geometric leveling. It consists of six (6) RRNN (Level Reference), shown in (Figure 5): Reference Level Igreja de São Pedro (RNSP), Reference Level Igreja Nossa Senhora do Carmo (RNSC), Reference Level Ladeira da Sé (RNLS), Reference Level Sétima estação da via sacra (RN7E), Reference Level Rua Prudente de Moraes (RNPM), Reference Level Mercado da Ribeira (RNMR) and Reference Level Ladeira da Misericórdia (RNLM). These were materialized with pins with spherical surfaces implementd in the curb and sidewalks.

- Planialtimetric Field of reference points

The planialtimetric field points were implemented by Total Station through the forward intersection methods and trigonometric leveling. It is composed of fourteen high and inaccessible targets located in the Towers of Churches: Igreja Nossa Senhora da Misericórdia (IGRM_1, IGRM_2, IGRM_3), Igreja Catedral da Sé (SÉT1_3, SÉT1_4, SÉT1_5, SÉT1_8, SÉT2_6, SÉT2_7, SÉT2_10, SÉT2_11), Igreja Nossa Senhora do Carmo (INSC_P_DIR and INSC_P_ESQ) and Water Tower Box of the Historic Site of Olinda (CXQESQ). Figure 5 shows the field points formed by the high targets, located in the Towers of Churches. (Figure 6) illustrates the high targets observed.

Figure 6 - Targets in the tops of Churches: Nossa Senhora da Misericórdia, Catedral da Sé and Igreja Nossa Senhora do Carmo. Photos: October 2011. Source: SOUZA (2012).

For the determination of the altimetric coordinates of the high targets, were used the orthometric height of the reference points, determined from a network leveling, compose the altimetric field reference points implemented in the test area.

Below is discussed the implementation set of the field reference points.

4.3 Field Points Measurement

4.3.1 Field Reference Points Measurement with GNSS

The Field Reference Points measurements with GNSS were held on 04/10/2010, 08/11/2010 and on 17/01/2011. Figure 7 shows the receivers GNSS on the stations composing the field reference points measured with GNSS.

Figure 7 - GNSS occupation of the reference points: BVM, MR, IGRM and HOUSE 43. Photos: November 2010. Source: SOUZA (2012).

Measurements made with GNSS campaigns were performed with two geodesic receivers L1/L2, Hiper Lite model, with horizontal accuracy of 3mm + 0.5 ppm and vertical 5mm + 0.5 ppm for static surveying, configured with the data recording rate 15 seconds, the elevation mask 15° and the screening time per station approximately 1 hour and thirty minutes. The stations RECF (RBMC) and UFPE were used as reference stations.

4.3.2 Field Reference Points Measurement with Digital Level

The measurement campaign was carried out in four days: 11/07/2011, 13/07/2011, 14/07/2011 and 15/07/2011.
The altimetric reference system of the RRNN implemented is fixed by the altitude RN394D from IBGE, located to the left of the main door of the Church São Pedro, corresponds to 15.9082 m height, adjusted in the date 15/06/2011. The experiments were conducted around several urban blocks entirely built by the pathway involving RRNN (RNSP, RNSC, RNLS, RNLM, RN7E, RNPM) RN394D and RNSP, making closed leveling circuits. (Figure 8) shows the urban street blocks understood by leveling circuits.

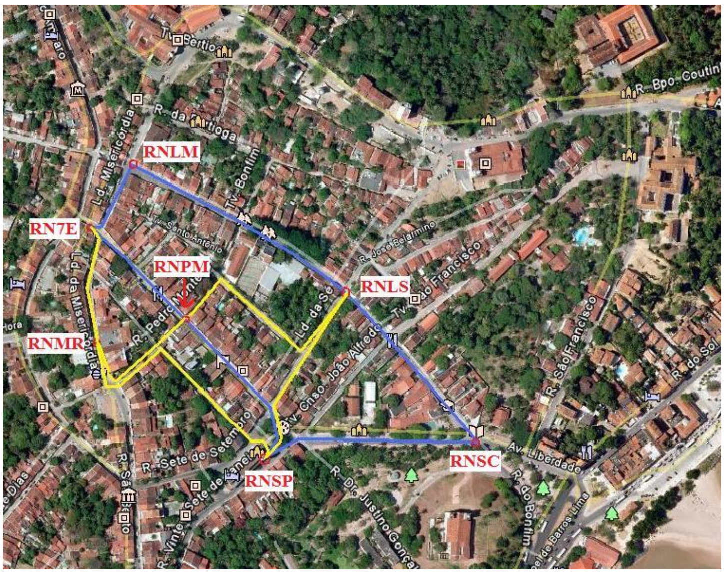

Figure 8 - Sketch in aerial view of the location of RRNN. Image: *Google Earth* 2009. Source: SOUZA (2012).

Measurements were taken with the Leica Digital Level DNA - 03, standard deviation of 0.3 mm/km Invar cod 2m, conducted continuously from pathway stations by forward and backward sights. The measurements were performed with the equipment as follows: the instrument is programmed to perform four successive measurements, at the end in the display presents the mean and standard deviation of the height measurement and informed the horizontal distance from the equipment to the Invar cod with deviation of 5 mm/10m. The results of measurements presented in the display are considered the influence of the curvature of the earth, ie. , the "EC" function was activated to correct the curvature of the earth. This means that electronically heights of the cods measurements were automatically corrected in relation to the earth curvature.

4.3.3 Field Reference Points Measurement with Total Station

The surveying in the Local Topographic System of the field reference points, applying the terrestrial measurement methods with the use of Total Station Trimble DR - 3305, accuracies 5" angle and 5 mm ± 5 ppm linear, was performed on different days: 17/12 /2011, 19/12/2011 and 20/12/2011.

All the stations of planimetric reference (see item 4.2) were filled with forced centering, ie., the tripods and the installed leveling bases in the two stations remain centered during the measuring procedure, by applying the technique of target combined measuring with two readings series in direct and inverse positions.

From the planimetric coordinates of the stations and altimetric field points were measured with a Total Station the targets located high in the Towers of Churches. By means of the forward intersection method and the trigonometric leveling were determined the planialtimetric coordinates of the high targets.

The high targets of the towers of the Catedral da Sé were measured at their left and right extremes because they had a spherical shape. The targets of the high tower of the Igreja Nossa Senhora da Misericórdia and the targets of he high tower of the Igreja Nossa Senhora do Carmo were measured in their extreme points (SOUZA, 2012).
The angular and linear measurements for the planimetric stations and for the Level References were made with a prism installed in the in "basis - prism" adapter in the first case and a vertical stick supported on a tripod in the second case. Thus it was possible to carry the RRNN altitude for other high targets observed.
From the high targets were possible by the backward intersection method to determine and compare the planimetric coordinates of the some stations of the planimetric field of reference points. And by the trigonometric leveling method verify the quality of the altitudes transferred from of the high targets to the Level References without considering the height of the instrument. This was possible because near each planimetric station there is a Reference Level.

5. RESULTS

Following are the results for the high targets located in the Towers of Churches of Nossa Senhora do Carmo, Nossa Senhora da Misericórdia and Catedral da Sé.

1) Planimetric coordinates of high targets determined by the forward intersection method of the 2D
The planimetric coordinates of high targets: IGRM_1, IGRM_2, IGRM_3, SÉT1_3, SÉT1_4, SÉT1_5, SÉT1_8, SÉT2_6, SÉT2_7, SÉT2_10, SÉT2_11, INSC_P_ESQ, INSC_P_DIR and CXQESQ were calculated using developed applications in EXCEL spreadsheet software. The resulting coordinates for these high targets are achieved by the average values of the observations of the angles reading in the edges left and right of the spherical structures located in the towers of the Catedral da Sé. For other targets coordinates are obtained by the mean values of the observations of the reading angles. In (SOUZA, 2012) described the whole procedure for the forward intersection method. Table 1 shows the determined coordinates and their respective standard deviations.

Table 1 - Coordinates UTM SIRGAS2000 determined by forward intersecting 2D and their respectives standard deviations. Source: SOUZA (2012).

Targets high	E (m)	N (m)	σE (m)	σN (m)
IGRM_1	295858,2736	9113796,3834	0,0004	0,0013
IGRM_2	295864,2755	9113801,7995	0,0002	0,0003
IGRM_3	295862,1408	9113796,0033	0,0006	0,0013
SÉT1_3	296184,1965	9113689,5429	0,0015	0,0019
SÉT1_4	296186,3237	9113692,8684	0,0171	0,0213
SÉT1_5	296175,9163	9113692,2235	0,0035	0, 0043
SÉT1_8	296182,7078	9113688,3695	0,0033	0,0041
SÉT2_6	296170,9975	9113710,1249	0,0040	0,0048
SÉT2_7	296184,9748	9113725,8490	0,0029	0,0028
SÉT2_10	296180,2481	9113718,2958	0,0067	0,0063
SÉT2_11	296188,0993	9113716,3503	0,0050	0,0053
INSC_P_ESQ	296189,4178	9113339,6978	0,0337	0,0148
INSC_P_DIR	296189,8834	9113343,1394	0,0138	0,0305
CXESQ	296100,4884	9113745,1810	0,0000	0,0000

2) Planimetric coordinates of the reference stations determined by backward intersection 2D

through combined measurements of direction and distance

The points coordinates AUX1, EL, INSC, BVM, MR and IGRM were determined by backward intersection through combined measurements of direction and distance (cf. section 3.2.2), using developed application in EXCEL spreadsheet software. (Table 2) shows the coordinates of the intersection points determined by the backward intersection and their respective standard deviations.

Table 2 - Coordinates UTM SIRGAS2000 determined by backward intersection 2D and their respective standard deviations. Source: SOUZA (2012).

Stations	E (m)	N (m)	σ_E (m)	σ_N (m)
IGRM (Q – 62 e IGRM_1)	295852,2358	9113770,8341	0,0000	0,0002
MR (EB – 105 e RNMR)	295794,4212	9113501,4990	0,0000	0,0000
CASA43 (RNSP e IGRM_3)	295988,6045	9113379,1729	0,0002	0,0010
INSC (AUX1 e IGRM_1)	296221,3443	9113399,6584	0,0013	0,0034
INCS (AUX1 e IGRM_2)	296221,4605	9113399,2570	0,0013	0,0034
INSC (AUX1 e IGRM_3)	296221,4462	9113399,3070	0,0013	0,0034
INCS (AUX1 e SÉT1_3)	296221,3472	9113399,3643	0,0171	0,0443
INCS (AUX1 e SÉT1_4)	296221,3196	9113399,3347	0,0443	0,0171
BVM (MR e SÉT1_3)	295811,4747	9113452,8674	0,0000	0,0000
BVM (MR e SÉT1_4)	295811,4888	9113452,8725	0,0000	0,0000
BVM (MR e SÉT1_8)	295811,6730	9113452,9395	0,0000	0,0000
AUX1 (INSC – SÉT1_4)	296177,3710	9113386,7119	0,0145	0,0377
AUX1 (INSC – SÉT1_3)	296177,3776	9113386,7333	0,0166	0,0432

c) Altimetric coordinates of the reference stations and of the high targets determined by trigonometric leveling method

The coordinates of the high targets of the church towers (IGRM_1, IGRM_2, IGRM_3, SÉT1_3, SÉT1_4, SÉT1_5, SÉT1_8, SÉT2_6, SÉT2_7, SÉT2_10, SÉT2_11, INSC_P_ESQ, INSC_P_DIR) had their altimetric coordinates calculated from multiple alignments as described in (Table 3).

Table 3 - Altimetric coordinates of the high targets of the churche towers calculated from multiple alignments. Source: SOUZA (2012).

HIGT ALTITUDE OF TARGETS (M)							
Targets high	ALIGNMENT						
	HOUSE 43-IGRM 3	EB 105-MR	BVM-MR	IGRM-Q-62	Q- 62-IGRM	INSC-AUX1	AUX1-INSC
HIGRM_1	72,2874	72,0168	-	71,7944	71,9265	72,3010	-
HIGRM_2	-	72,5670	-	-	-	72,1155	-
HIGRM_3	-	72,0692	-	72,0257	72,0394	71,5190	-
HSÉT1_3	70,5076	70,4079	70,3944	70,2461	-	70,3672	70,3690
HSÉT1_4	74,2168	74,0791	74,0912	73,9350	74,0283	74,0922	74,0863
HSÉT1_5	70,41635	70,3735	70,3641	-	-	70,2041	70,2353
HSÉT1_8	69,6003	69,6567	69,7617	-	-	-	69,8356
HSÉT2_6	69,2586	69,2798	69,3969	-	-	69,6679	-
HSÉT2_7	71,7518	-	71,0059	-	-	71,3309	-
HSÉT2_10	-	73,8634	73,8978	-	-	-	74,1922
HSÉT2_11	70,7794	70,5452	-	-	-	-	-
H INSC_P_ESQ	-		-	-	-	34,5874	34,6040
H INSC_P_DIR	-		-	-	-	33,1802	33,1600

The final altimetric coordinates (Table 4) of the high targets of the churche towers are the resultant of the average of the calculated coordinates for each high target.

Table 4 - Means of the altimetric coordinates of the high targets of the towers. Source: SOUZA (2012).

High Targets	Averages of altitudes (m)
IGRM1	72,06520
IGRM2	72,34127
IGRM3	71,91333
SÉ-T1_3	70,38201
SÉ-T1_4	74,07557
SÉ-T1_5	70,31868
SÉ-T1_8	69,71358
SÉ-T2_6	69,40078
SÉ-T2-7	71,36287
SÉ-T2-10	73,88061
SÉ-T2_11	70,66227
INSC_P_ESQ	34,59571
HINSC_P_DIR	33,17009

From the average altitudes of high targets of the churches (Table 4) and various alignments (Table 3) made by the trigonometric leveling method were recalculated the RRNN altitudes and performed the comparison with the altitudes those obtained from altimetric field points determined by the geometric leveling method. It was found that the discrepancies between the altitudes with respect to the same high target and the various alignments were not satisfactory, necessitating a more detailed study of the trigonometric leveling in determining high targets.

6. FINAL CONSIDERATIONS

Were implanted three fields of reference points with different technology measurements. The first with the use of GNSS, the second with the use of Digital Level and the third with the use of Total Station. This set of field reference points allows realize Topographic/Geodesic Surveys and 3D Reconstruction of the objects within their areas and their surroundings. In this sense the Historical Site of Olinda was awarded with the implementation of the planialtimetric geodesic structures.

The planialtimetric field of pointes (IGRM_1, IGRM_2, IGRM_3, SÉT1_3, SÉT1_4, SÉT1_5, SÉT2_6, SÉT2_7, SÉT1_8, and SÉT2_10 SÉT1_11, QCXEsq, INSC_P_DIR and INSC_P_ESQ) had its coordinates determined by with the Total Station by the method of forward intersection from the planimetric field of reference points and by the method of trigonometric leveling from the altimetric field of the reference points .

Considering the standard deviations of the planimetric coordinates, presented in Table 1, determined by the forward intersection, was noted that the largest deviations was found for the INSC_P_ESQ high target with value 0.0337 m to the coordinate E and 0.0305 m for the - coordinate N of the high target INSC_P_DIR. The lowest values of the standard deviations are found for the coordinates E and N of the high target IGRM_2, with values of 0.0002 m and 0.0003m, respectively.

As the altimetric coordinates of the high targets were not adjusted, the quality control of them was performed through of the dispersion around the mean. However analyzing the orthometric heights of RRNN determined by trigonometric leveling and the ones calculated by trigonometric levelind from the altitudes of the high targets, were found discrepancies unacceptable for most high targets, with exception for the targets INSC_P_ESQ, INSC_P_DIR and SÉT1_4 whose their discrepancies were around 1cm.

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